Overdamped electron plasma oscillations in cubic $Al_xGa_{1-x}N$ layers observed by Raman scattering spectroscopy

J.R.L.Fernández[1] , A. Tabata[1,2], V.A. Chitta[1], D.J. As[3], T. Frey[3], O.C. Noriega[1], E. Abramof[4], D. Schikora[3], K. Lischka[3], and J.R. Leite[1]

[1] Instituto de Física, Universidade de São Paulo, CP 66318, 05315-970 São Paulo, SP, Brazil.
[2] Faculdade de Ciências de Bauru, UNESP, CP 473, 17033-360, Bauru, SP, Brazil.
[3] Universitat Paderborn, FB-6 Physik, D-33095 Paderborn, Germany.
[4] Instituto Nacional de Pesquisas Espaciais (INPE-LAS), CP 515, 12201-970 São José dos Campos, SP, Brazil.

Contact author: tabata@macbeth.if.usp.br

Longitudinal optical (LO) phonon-plasmon coupled modes in n-type cubic (c-) $Al_xGa_{1-x}N$ epitaxial layers are investigated by Raman scattering measurements. The carrier concentrations and mobilities in our samples are such that the plasmon damping constant Γ is larger than the plasma frequency ω_p. This condition implies that the c-$Al_xGa_{1-x}N$ layers are overdamped plasma systems which is confirmed by the lineshape analysis of the measured Raman spectra.

The $Al_xGa_{1-x}N$/GaN layers ($0.07<x<0.25$) were grown by Molecular Beam Epitaxy (MBE) on GaAs(001) substrate using a radio-frequency plasma nitrogen source. The c-GaN buffer layers of about 350 nm thick were grown at T=720°C. The c-$Al_xGa_{1-x}N$ films of about 400 nm thick were deposited at T=835°C. The cubic structure, crystalline quality, Al composition and thicknesses of the films were determined by Rutherford backscattering spectroscopy (RBS) and high resolution X-ray diffraction (HRXRD) experiments.[1]

The nominally undoped c-$Al_xGa_{1-x}N$ layers show a very high electron concentration ($n \approx 10^{20}$ cm^{-3}) displaying a metallic behavior in the range of temperature from 10 to 300 K. The resistivity of our samples as a function of inverse temperature is shown in Figure 1. The Hall carrier concentration and mobility as a function of temperature for the layers were also measured and the obtained results at 300 K are shown in Table I. The low values found for the mobility, which correspond to low values for the collision relaxation time for the electrons, make the condition for the plasmon to be overdamped ($\Gamma > \omega_p$) valid for all the samples analysed here.

Figure 2 depicts typical Raman spectrum observed for the $Al_xGa_{1-x}N$ layers. Results are shown for the alloy layer with Al composition x=0.2. The measurements were carried out in backscattering geometry using an excitation energy of 2.41 eV. The main feature observed in the spectrum is the broad band covering a large region between the TO (567cm^{-1}) and the LO (774cm^{-1}) of the alloy, indicated by arrows in the Figure. The LO-mode frequency, not observed in the spectrum, was estimated from recent Raman studies on phonon modes in c-AlGaN alloy.[2] A spectral lineshape analysis shows that this broad band arises from overdamped plasmon-phonon scattering dominated by a charge-density-fluctuation mechanism.[3] A lineshape fitting analysis of the Raman spectra is performed and parameters such as collision relaxation time and effective mass of the electrons in the $Al_xGa_{1-x}N$ alloys are determined.

References

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Table I. Electron concentration, n, and mobility, μ, for c-$Al_xGa_{1-x}N$ layers.

x	n(10^{20} cm^{-3})	μ(cm^2/ Vs)
0.07	4.12	21.76
0.09	3.44	21.35
0.12	6.06	14.82
0.16	6.20	15.89
0.20	1.32	5.5
0.25	26.4	0.52

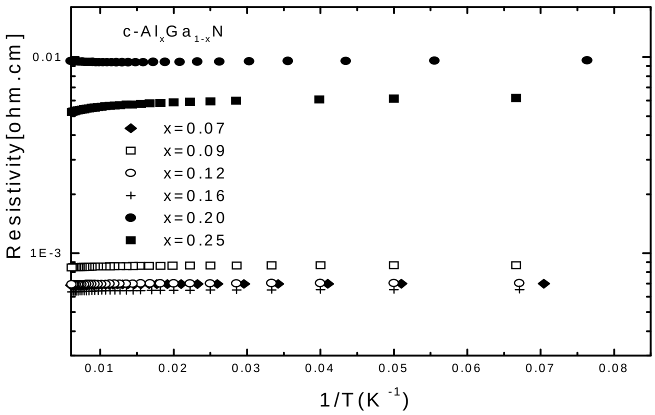

Figure 1. Resistivity as a function of inverse temperature for the c-$Al_xGa_{1-x}N$ layers. The alloy composition of each sample is indicated.

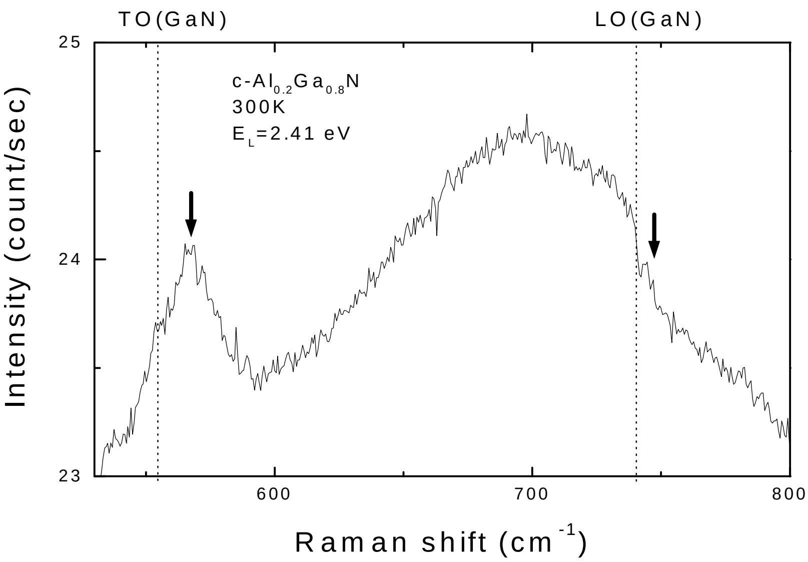

Figure 2. Raman espectrum of the c-$Al_{0.2}Ga_{0.8}N$ sample. The dashed lines indicate the TO (555 cm^{-1}) and LO (741 cm^{-1}) phonon modes of c-GaN. The arrows mark the TO and the expected position of the LO at higher energy, of the alloy. The excitation energy E_L is 2.41eV.